

**The University of Toronto  
National Biology Competition**

**2003 Examination**

Time: 75 minutes

Number of questions: 50

General Instructions

- C Do not open this booklet until you are instructed to do so.
- C Print your name at the top of this booklet.
- C Indicate all of your answers to the questions on the separate Response Form. No credit will be given for anything written in this booklet, but you may use the booklet for notes or rough work. No additional time will be given after the exam to transfer your answers to the Response Form.
- C After you have decided which of the suggested answers is best, COMPLETELY fill in the corresponding bubble on the Response Form. Give only one answer to each question. If you change an answer, be sure that the previous mark is erased completely.
- C Use your time effectively. Do not spend too much time on questions that are too difficult. Go on to other questions and come back to the difficult ones later if you have time. It is not expected that everyone will be able to answer all questions.
- C Good luck and have fun!

*Should you guess the answers to questions about which you are not certain?*

Since your score on the exam is based on the number of questions you answered correctly minus one-third of the number you answered incorrectly, it is improbable that guessing will improve your score (it is more likely to lower your score). (No points are deducted or awarded for unanswered questions.) However, if you are not sure of the correct answer but have some knowledge of the question and are able to eliminate one or more of the answer choices, then your chance of getting the right answer is improved, and it may be advantageous to answer such a question.

1. Water is the most abundant substance in all organisms. Next to water, the major components of living cells are:
  - a. lipids.
  - b. vitamins.
  - c. carbohydrates.
  - d. nucleotides.
  - e. proteins.
  
2. You are given a nucleic acid that you think is single-stranded DNA, but you are not sure. You analyse the nucleotide composition of the sample. Which of the following compositions would confirm your thinking?
  - a. Adenine 38% – Cytosine 12% – Guanine 12% – Uracil 38%
  - b. Adenine 22% – Cytosine 32% – Guanine 17% – Uracil 29%
  - c. Adenine 22% – Cytosine 32% – Guanine 17% – Thymine 29%
  - d. Adenine 38% – Cytosine 12% – Guanine 12% – Thymine 38%
  - e. None of the above, as this methodology will not resolve the matter.
  
3. At which stage in mitosis do chromosomes meet and line up in the middle of the cell?
  - a. Prophase
  - b. Interphase
  - c. Anaphase
  - d. Telophase
  - e. Metaphase
  
4. The Government of Canada recently signed the Kyoto Protocol. Which of the following contributes towards meeting the targets of reducing greenhouse gases?
  - a. Planting trees.
  - b. Clear-cutting forests to grow crops.
  - c. Increasing the output of oxides of nitrogen (gases) into the atmosphere.
  - d. Increasing the amount of methane in the atmosphere.
  - e. A world-wide increase in the number of livestock.
  
5. A scientist measured the uptake of glucose into an animal cell. When the cell was placed in a 0.1 M glucose solution, no uptake was measured, but when it was placed in a 0.7 M solution, uptake occurred. When a substance that inhibits respiration in the mitochondrion was added to the cell, uptake still occurred in the 0.7 M solution, but it also occurred in the 0.1 M solution. Which statement is **NOT** supported by these observations?
  - a. Glucose is taken up into the cell by passive transport.
  - b. When respiration is inhibited, the concentration of glucose in the cytoplasm decreases.
  - c. The rate of glucose uptake is related to the difference in glucose concentration inside and outside the cell.
  - d. The concentration of glucose in the cytoplasm of the animal cell is normally less than 0.1 M.
  - e. Energy from respiration in the mitochondrion is used to synthesize glucose.

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6. Which of the following did **NOT** influence the formulation of Darwin's theory of evolution?
- Lyell's theories on geological change, which indicated that Earth must be very old.
  - The resemblance between the fauna of South America and the fauna of the Galapagos Islands.
  - Mendel's crossing experiments with peas.
  - Malthus' theories on population growth and competition.
  - The development of new varieties by plant and animal breeders.
7. A scientist develops a drug that she thinks might inhibit the release of gonadotropin-releasing hormone (GnRH) from the hypothalamus. Some volunteer female subjects take the drug. Which of the following results obtained from the volunteers would support the scientist's hypothesis?
- Increased levels of oestrogen in the blood.
  - Earlier onset of menstruation.
  - Follicle development.
  - Decreased levels of luteinizing hormone in the blood.
  - Enlargement of the breasts.
8. A doctor discovers her patient can resist many bacterial infections by producing appropriate antibodies, but the patient is highly susceptible to viral infections. The most likely diagnosis is a disorder of the patient's:
- T cells.
  - macrophages.
  - plasma cells.
  - erythrocytes.
  - B cells.
9. Having one cotyledon distinguishes monocot seeds from dicot seeds. What other feature is unique to monocots?
- The nutrients required for germination are stored in the endosperm.
  - The shoot apical meristem is present at the time of germination.
  - The embryonic root is the first organ to penetrate the seed coat.
  - The root apical meristem is protected by a root cap.
  - The embryo is surrounded by a protective seed coat.
10. Which of the following sets of values would result in a population with a growth rate of zero?  
( $b$  = births,  $d$  = deaths,  $i$  = immigration,  $e$  = emigration)
- $b = 1000, d = 500, i = 750, e = 1000$
  - $b = 1000, d = 500, i = 1000, e = 1000$
  - $b = 1000, d = 500, i = 1500, e = 1000$
  - $b = 1000, d = 500, i = 0, e = 1000$
  - $b = 1000, d = 500, i = 500, e = 1000$
-

11. You perform the following dihybrid genetic cross:

$$AAbb \times aaBB$$

where:  $A$  = big (dominant)  
 $a$  = small  
 $B$  = dark (dominant)  
 $b$  = light

In the  $F_1$  generation all of the progeny are big and dark. You now self the  $F_1$  progeny and score 100 of the resulting  $F_2$  progeny. How many of the  $F_2$  progeny would you expect to be big and light?

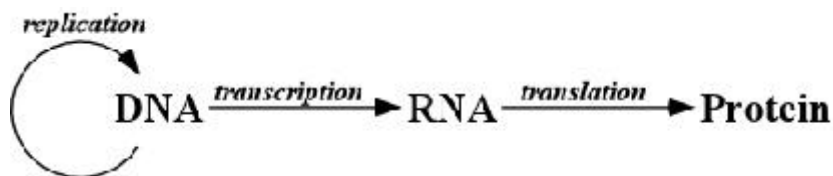
- a. 1/16
  - b. 3/16
  - c. 1/4
  - d. 9/16
  - e. 3/4
12. Which statement is true only for organisms belonging to the kingdom Fungi?
- a. They are multicellular and photosynthetic.
  - b. They have cell walls and reproduce by seeds.
  - c. They have filamentous growth and cell walls made of chitin.
  - d. They have roots and starch is the main storage molecule.
  - e. They have numerous cellular organelles, but only one nucleus per cell.
13. The mass of an atom is primarily determined by the:
- a. number of electrons it contains.
  - b. number of protons it contains.
  - c. number of neutrons it contains.
  - d. sum of the number of protons and electrons it contains.
  - e. sum of the number of protons and neutrons it contains.
14. A cell cycle consists of
- a. mitosis and meiosis.
  - b. G1, the S phase, and G2.
  - c. prophase, metaphase, anaphase, and telophase.
  - d. interphase and mitosis.
  - e. meiosis and fertilization.

15. Which of the following is responsible for the alpha-helical structure of proteins?
- Hydrophobic interactions
  - Nonpolar covalent bonds
  - Ionic interactions
  - Hydrogen bonds
  - Polar covalent bonds
16. In addition to lungs, I have air sacs among my internal organs and inside some of my bones. My breast bone (sternum) is large to allow for the attachment of large powerful muscles. I do not have a urinary bladder; uric acid and faeces are excreted together as a semi-solid. What am I?
- An amphibian (e.g., frog)
  - A bony fish (e.g., salmon)
  - A bird (e.g., hawk)
  - A cartilaginous fish (e.g., shark)
  - A lizard (e.g., iguana)
17. Which statement explains why parasitic bacteria typically evolve more quickly than their hosts?
- Bacteria are always under stronger selection than their hosts.
  - Bacteria lack DNA.
  - Infection by these parasites usually kill the hosts, but not the bacteria.
  - Bacteria usually have a shorter generation time than their hosts.
  - Bacteria reproduce sexually.
18. Suppose you were working in a diagnostic laboratory and had measured high levels of glucagon and low levels of insulin in a blood sample from a patient. What would be the most likely explanation?
- The patient had consumed a large soft drink on the way to the lab.
  - The patient was suffering from diabetes.
  - The patient had not eaten anything for several hours.
  - You had made an error in one or both of the measurements.
  - The patient was suffering from cancer of the pancreas.
19. Which statement is **CORRECT**?
- Endocytosis takes place in the endoplasmic reticulum.
  - Human cells do not undergo exocytosis, since the elimination of waste products is carried out by the excretory system.
  - During the process of endocytosis, particles enter the cytoplasm through a transient pore in the plasma membrane.
  - During the process of exocytosis, vesicles in the cytoplasm pass through the plasma membrane and discharge their contents outside the cell.
  - During the process of exocytosis, the plasma membrane increases in surface area.

20. Both phloem sieve tube cells and xylem vessel cells are derived from the same kind of precursor cell, but at maturity they are very different. What feature is unique to phloem sieve tube cells?
- The cell membrane remains intact in a mature functioning cell.
  - The nucleus is firmly attached to the cell membrane.
  - The cell wall is rigid because of the deposition of lignin.
  - The cell undergoes programmed cell death during development.
  - The cell contributes to the mechanical support of the stem.

21. In 1956 Francis Crick coined the phrase “central dogma” to describe the information flow from DNA to protein (as illustrated below). Although it is still essentially valid, an observation coming out of the Human Genome Project has added substantial complexity to this seemingly simple relationship. What is this complexity?

- Horizontal gene transfer
- Prions
- Jumping genes
- Introns
- Alternative splicing of mRNA



22. The general structure of all amino acids is the same, but each amino acid has a different:
- side chain.
  - aldehyde group.
  - amino group.
  - peptide backbone.
  - carboxyl group.
23. Two different animals are classified into the same Family. This means they would be classified in:
- the same Phylum, but different Class.
  - the same Class, but different Species.
  - a different Kingdom and a different Phylum.
  - a different Class and a different Order.
  - the same Genus, but different Phylum.
24. Chromosome number is reduced during meiosis because the process consists of:
- two cell divisions without any chromosome replication.
  - a single cell division without any chromosome replication.
  - two cell divisions in which half of the chromosomes are destroyed.
  - two cell divisions and only a single round of chromosome replication.
  - four cell divisions with no chromosome replication.

25. Some animal cells growing in a liquid culture medium (in an open beaker covered with a mesh screen to keep out bacteria) were placed in a sealed glass container containing a large healthy green plant. The container was placed in an incubator with lights that came on for 12 hours per day. At the end of the first light period, the animal cells were healthy, but at the end of the subsequent dark period they were all dead. Which statement best explains these observations?
- The animal cells were killed by lactic acid, which is formed by respiration in the dark.
  - The plant gave off toxic organic molecules in the dark.
  - In the dark, the plant used up all the oxygen in the container.
  - Animal cells need light to be able to grow.
  - In the light, the animal cells produced oxygen through respiration, but this process is inhibited in the dark.
26. A scientist measures the average tail length of a wild population of birds over a period of 10 generations. During this period, he observes a gradual increase in average tail length. Which process could account for this increase?
- Genetic drift
  - Emigration
  - Natural selection
  - Immigration
- i only
  - i and iii only
  - ii and iv only
  - i, ii, iii, and iv
  - iii and iv only
27. Which of the following molecules diffuse easily through a plasma membrane?
- Ethyl alcohol
  - Glucose
  - Adenosine triphosphate
  - Pyruvic acid
  - Amino acids
28. Which of the following would **NOT** be associated with a decrease in the conduction velocity of nerve impulses in a neuron?
- Increasing the length of the axon.
  - Removing the myelin sheath.
  - Cooling the axon.
  - Reducing extracellular  $\text{Na}^+$  concentration.
  - Decreasing the diameter of the axon.

29. The *lac* operon of *E. coli* is a segment of DNA that includes a promoter, an operator, and three structural genes that code for lactose-metabolizing enzymes. In the *lac* operon, RNA polymerase:
- binds to the operator when the repressor is activated by lactose.
  - binds to the promoter region when the repressor is inactivated by lactose.
  - is inactivated by binding to the repressor protein.
  - is coded for by the structural gene of the *lac* operon.
  - binds to the promoter when lactose activates the repressor protein and the lactose-repressor complex binds to the operator.
30. If someone had their gall bladder removed, which food would they have the hardest time digesting?
- Salad greens
  - White bread
  - Fatty bacon
  - Skim milk
  - Apples
31. In a hormonal control system, hormone X inhibits the secretion of substance Y. If this system works by positive feedback, which of the following would be **CORRECT**?
- Substance Y stimulates the production of hormone X.
  - Secretion of substance Y should stop completely.
  - Levels of hormone X should not be affected by levels of substance Y.
  - Levels of substance Y will stabilize at a moderate level.
  - Both (a) and (d) are correct.
32. Which of the following is least likely to result in density-dependent effects on the growth of natural populations?
- Interspecific competition
  - Parasitism
  - Disease
  - Increased rainfall
  - Migration
33. Which statement about genetic mutations is **FALSE**?
- Only mutations that occur in the cells that produce sperm and eggs can be transmitted to the next generation.
  - Beneficial mutations are rare.
  - Mutations occur during the process of DNA replication.
  - Dominant lethal mutations can be passed on to the next generation by heterozygous individuals.
  - Mutations that increase an individual's fitness (reproductive success) are favoured by natural selection.



34. If  $\Delta G$  of a chemical reaction is negative and the change in entropy is positive, what can one conclude about the reaction?
- It is endergonic.
  - It is exergonic.
  - It requires energy.
  - It is anabolic.
  - It will not reach equilibrium.

35. You map four bacteriophage genes by recombination. The recombination frequencies between the four genes are shown in the table below. What is the order of the genes along the chromosome?

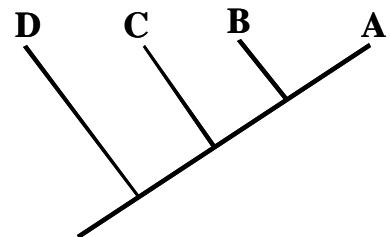
- A B C D
- C B D A
- B A D C
- C A B D
- D A C B

	A	B	C	D
A	-	0.18	0.1	0.2
B		-	0.15	0.37
C			-	0.24
D				-

36. Which evolutionary process would best account for the observation that there is a striking similarity in both form and function between the enlarged horns observed in males of some insects and some mammals?
- Descent with modification
  - Evolution by natural selection
  - Convergent evolution
  - Rapid speciation
  - Gene flow
37. A scientist compared the multiplication rates for two species of bacteria in their natural habitats: one which lived in the mouth of sheep, and one that lived in the sheep's rumen (part of the stomach). She found that the bacteria in the sheep's mouth multiplied much faster than that in the rumen. Which of the following hypotheses best explains these observations?
- Bacteria are photosynthetic, so the bacteria in the rumen do not get enough light to photosynthesize.
  - The bacteria in the rumen live in an anaerobic environment, and anaerobic respiration does not produce as much energy as aerobic respiration.
  - The sheep's mouth is warmer than the inside of the rumen, so bacterial respiration is faster and produces more energy than in the rumen.
  - Fermentation occurs in the sheep's mouth, which produces more energy than aerobic respiration.
  - There is less food for the bacteria in the sheep's rumen than in the mouth.

38. Which of the following is **NOT** required for the size of a given trait to evolve by natural selection?
- The size of the trait varies among individuals in the population.
  - There is a relationship between the size of the trait and the fitness (reproductive success) of the bearer of the trait.
  - The size of the trait has a genetic basis.
  - Individuals with larger traits live longer.
  - Both (a) and (b) are not required.
39. With respect to the blood, the mammalian kidney does **NOT** have an important role in maintaining which of the following?
- Water content
  - Osmotic concentration
  - Blood pressure
  - Salt levels
  - Glucose levels
40. Which of the following is **NOT** in the phylum Mollusca (mollusks)?
- Clam
  - Oyster
  - Shrimp
  - Snail
  - Squid
41. A scientist grew some plant cells in a liquid culture medium in the light. When he looked at the culture, it appeared green. He then added some sugar to the medium and turned off the lights. After a few days, the culture appeared white, but when he examined a few drops of the culture under the light microscope using the 10x objective, he counted twice as many cells per millilitre than had been present before he turned the lights off. Which is the best explanation of these results?
- The plant cells died, and the cells seen under the microscope were bacteria that had used the sugar for food.
  - Because plant cells contain mitochondria, they used the energy from respiration to continue growing in the dark.
  - In the absence of light, chloroplasts turn into mitochondria and can use sugar for respiration.
  - In the dark, energy can be produced by chloroplasts as long as they have a source of sugar.
  - In the light, photosynthesis results in proteins being stored in the chloroplasts, and this protein can be broken down in the dark to release energy for cell growth.

42. The transport of sucrose in plants occurs by pressure flow through the sieve tubes of the phloem from a source (such as leaves where photosynthesis occurs) to a sink (such as a developing fruit where the photosynthetic products are used or stored). Which statement about phloem transport is **FALSE**?
- Sieve tubes in a source leaf have a low hydrostatic pressure.
  - Water and solutes move through the sieve tube along a pressure gradient.
  - Sucrose is actively transported across the cell membrane in sink tissue.
  - Sieve tube hydrostatic pressure is higher during the day than during the night.
  - Sucrose is swept along by the bulk flow of water in the sieve tubes.
43. Which statement about respiration in plant mitochondria is **FALSE**?
- Acetyl CoA accumulates between the inner and outer membranes.
  - The electron transport chain occurs within the inner membrane.
  - The citric acid (Krebs) cycle occurs in the matrix of the mitochondrion.
  - The concentration of protons is higher between the membranes than in the matrix.
  - ATP is generated through chemiosmosis.
44. The plant hormone auxin functions in apical dominance, the phenomenon whereby growth of the apical bud of the plant suppresses growth of the lateral buds. Which observation provides the strongest support for this fact?
- Addition of auxin to an intact apical bud maintains the growth suppression of the lateral buds.
  - Removal of the apical bud results in the growth of the lateral buds, while replacing the apical bud with a source of the plant hormone abscisic acid maintains the growth suppression of the lateral buds.
  - Removal of the lateral buds accelerates the growth of the apical bud.
  - Removal of the lateral buds and subsequent replacement with a source of auxin results in inhibition of the apical bud.
  - Removal of the apical bud results in outgrowth of lateral buds, while replacing the apical bud with a source of auxin maintains the suppression of lateral bud growth.
45. The phylogenetic tree below depicts a hypothesis of the relationships between four species. Species D is the outgroup that roots the tree. The branch lengths of the tree are proportional to evolutionary time. Which species is (are) most closely related to species C?



- Species A
- Species B
- Species A and B are equally related to species C.
- Species D
- Species B and D are equally related to species C.

46. Which statement about prokaryotes is **CORRECT**?
- They have membrane-bound organelles.
  - They are all autotrophic.
  - They possess a cell wall and a nucleus with a double membrane.
  - They lack ribosomes.
  - They reproduce asexually, but genetic recombination does occur.
47. A population of 100 diploid individuals is in Hardy-Weinberg equilibrium. If the frequency of the dominant allele is 40%, how many individuals are homozygous recessive?
- 48
  - 36
  - 24
  - 18
  - 16
48. A geneticist discovers a mutant plant with pale green leaves and subsequently determines that this mutant produces only half the normal amount of chlorophyll *a*. Which statement is the most accurate description of the impact of this mutation on photosynthesis?
- The plant can absorb only one half the normal number of photons.
  - There will be no effect on the light reactions of photosynthesis because the regeneration of ribulose 1,5-bisphosphate (RuBP) is the rate limiting step.
  - Synthesis of carotenoid pigments will compensate for the reduction in chlorophyll *a*.
  - The chloroplast will have half the number of photosystem I complexes, but photosystem II will be unaltered.
  - A doubling of the levels of glyceraldehyde-3-phosphate (G3P) will compensate for the loss of chlorophyll *a*.
49. What would be most likely to happen if decomposers (bacteria and fungi) went extinct on Earth?
- Detritivores (such as earthworms) would replace them.
  - Primary productivity would increase.
  - Nutrients would accumulate in dead plants and animals and become unavailable to living organisms.
  - Carnivores and herbivores would not be affected.
  - Food webs would lose one trophic level.
50. The normal haematocrit (percent red cells in blood) in a human male is around 42%. What is the most likely explanation for a person who is found to have a haematocrit of 50%?
- They are suffering from anaemia.
  - They live and work at high altitude.
  - They do a lot of scuba diving.
  - They are female.
  - The measurement is incorrect, because a haematocrit of 50% is impossible.